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COMPARATIVE ESTIMATES OF POST-CONSUMER SOLID WASTE

by Frank A. Smith*

Background and Purpose

With the increasing interest in resource recovery from municipal solid waste, many state, city, and regional governments are seriously reevaluating their solid waste disposal options. In the process of evaluating both design alternatives for processing plants and potential revenues from recovered materials, these agencies are finding that information on the quantity and composition of solid waste collection is more important to the economics of system design for resource recovery than was the case for traditional landfill and incinerator options.

As we perceive more interest in such information, we also see that a confusing variety of solid waste quantity estimates are in circulation, including significant differences among "official" OSWMP figures. For example, the widely used "old" figure of 5.32 lb/cap/day = 190 million tons (in 1967), which emanated from the preliminary results of the 1968 National Survey, is contradicted by the "new" figure of 3.32 lb/cap/day = 125 million tons (in 1971), which has recently been used in papers, speeches, and congressional testimony by OSWMP personnel.

This paper has two purposes. The first is to provide definition and context for both the "old" and the "new" figures, in order to minimize confusion and to point out that, in this business, there is no absolutely "correct estimate". The second purpose is to emphasize the necessity for extreme caution in applying any National average estimate to regional or local solid waste management or resource recovery planning and design efforts.

A Review of Selected Solid Waste Estimates

The 1968 National Survey. The 1968 National Survey of Community Solid Waste Practices represented a considerable effort to gather data from

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*Dr. Smith is an economist with the Resource Recovery Division (RRD), Office of Solid Waste Management Programs (OSWMP), U.S. Environmental Protection Agency (EPA).

field sources on a nationwide basis. Returns were ultimately received from communities representing 87 percent of the U.S. population. In retrospect, the Survey's major strength was its breadth of coverage, and its major weakness was felt to be that the communities did not have good data to provide. In particular, the vast majority of communities reported estimated rather than measured (weighed) data on solid waste. Coverage of commercial and industrial waste was especially spotty.

The final returns were never fully evaluated, and the principal published solid waste figures from the Survey were the preliminary results presented by Anton J. Muhich and Richard D. Vaughan at the 1968 October meeting of the American Public Works Association.[1] This was the origin of the 5.32 lb/cap/day = 190 million tons of solid waste figure which has been so widely used both within and outside EPA. It should be noted that these figures supposedly include reported demolition, construction, industrial, and other municipal solid waste, in addition to household, commercial, and institutional refuse of all kinds. Of the 5.32 lb/cap/day, only 4.15 was estimated as the household and commercial contribution to the nationwide average.

Paul Britton, a former OSWMP statistician, subsequently conducted a more rigorous evaluation of the complete returns from the 1968 Survey. Figures based on his best estimates from a selected sampling of the returns are presented in Table 1. For various reasons, it was difficult to establish a single best estimate for waste categories other than household, commercial, and institutional, but the ranges presented are nevertheless of interest.

The most serious criticism of the 1968 Survey is that it represented estimated rather than measured (weighed) data. Therefore, it must be regarded with great skepticism. Resource Planning Associates, Inc., (RPA), in work performed for the National Center for Resource Recovery, (NCRR),[2,3] has pointed out that the cities which reported measured (weighed) data showed consistently lower per capita values for virtually all waste categories than did the other respondents. Although we consider the sample size of communities reporting measured data to be too small to consider their per capita values valid for National estimating purposes (as was done by RPA), we do consider this as prima-facie evidence of a tendency of the survey to overestimate per capita waste. Thus, while accepting the RPA/NCRR qualitative conclusion that the 1968 Survey data overestimated waste to some degree, we still question the quantitative extent of the difference in household municipal waste implied by NCRR's published figure of 115 million tons for the municipal solid waste stream in 1972 (exclusive of industrial and demolition waste).

A second kind of evidence supporting a thesis that the 1968 Survey overestimated the household-commercial-institutional component of municipal waste was first propounded by Darnay and Franklin in 1970.[4] This was in reference to the apparent contradiction between the reasonably

Table 1

REVISED ESTIMATES OF NATIONWIDE SOLID WASTE COLLECTION FOR 1967, BASED ON THE 1968 NATIONAL SURVEY OF COMMUNITY SOLID WASTE PRACTICES*

Sources	Total 1967 Collected (million tons)		Average Per Person (Pounds/Day)	
Residential	88		2.43	
Commercial and Institutional	57		1.58	
Subtotal	145		4.01	
	Low Estimate	High Estimate	Low Estimate	High Estimate
Other Municipal+	6	22	0.17	0.61
Demolition and Construction	5	19	0.13	0.53
Industrial	34	105	0.95	2.90

*Britton, P. Environmental Protection Agency analyses of final questionnaire returns received by the 1968 National Survey of Community Solid Waste Practices. Unpublished data, May 1970. Average per person (pounds/day) values estimated by Britton were converted to total 1967 annual tonnages on the basis of estimated 1967 U.S. population of 198.7 million.

+Includes street and alley cleanings, tree and landscaping, park and beach, and catch basin solids. Excludes sewage sludge.

"hard" estimates of the National quantity of paper and paperboard waste (based on well-known, annually published data on production, consumption, and recycling) and the measured percentage of paper material typically found in composition analyses. Thus, if 145 million tons of residential and commercial solid waste were collected in 1967, and if 35 to 50 percent of this waste were paper (as consistently shown in numerous sample composition analyses), it would follow that there are between 50 and 73 million tons of wastepaper. However, since the independently estimated quantity of wastepaper for 1967 was approximately 34 million tons (oven dry) and since only part of the difference could possibly be accounted for as moisture content in the wastepaper fraction, the conclusion is that either the 145 million tons is too high, or that 35 to 50 percent paper in the waste stream is too high. Many would contend that the "softest" number should yield in cases of contradiction. In this case, the 145-million-ton (4.01 lb/cap/day) figure is the softest of the three pieces of data. However, the question of how much moisture there actually is in the paper fraction of collected waste, plus the inherent ambiguities of most of the percentage composition studies, combine to preclude precise estimates and comparisons based on total paper.

Three further conclusions are suggested relative to the 1968 Survey. First, the 1968 Survey results have not been fully appreciated either by OSWMP personnel or by the public at large, because these results were never analyzed sufficiently and because the best analyses have not yet been published. Second, it is evident that the published results (i.e. 190 million tons and 5.32 lb/capita (1967) figures) have often been wrongly interpreted as being limited to conventional household and commercial types of refuse, rather than including the fuller range of construction, demolition, other municipal refuse, sewage sludge, and industrial process waste.* Third, there are two kinds of evidence to suggest that the 1968 Survey returns and the nationwide estimates which were based on them tended to overestimate collected municipal solid waste, although neither type of evidence can provide definitive proof regarding the extent of overestimate.

1971 Private Sector Collection Survey. As part of a study of the private sector refuse collection industry, Applied Management Sciences, Inc., (AMS) under contract to the National Solid Waste Management Association on a grant from the EPA, developed National estimates of

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*For example, Darnay and Franklin argued the "wastepaper paradox" in the context of 190 million tons of "municipal" waste, rather than in terms of a more relevant lower number more consistent with the types of household-commercial waste which provide the packer-truck samples for virtually all composition studies.

U.S. per capita waste generation (collection) for 1970.[5] Using large samples from private waste haulers, scaled up to National level totals on the basis of the estimated share of total customers covered by the private sector survey, AMS was able to estimate residential, commercial. and industrial solid waste. The AMS National estimates, modified to conform with our definition of residential and converted to 365/day/year basis, are shown in Table 2.

Methodologically, the AMS Private Sector study estimates for National waste levels resemble those of the 1968 National Survey in that both involve scaling-up of data from respondents on the basis of assumed population coverage. To a large extent, the AMS results also involve the calculation of weight data, based on counted or estimated volume collection data reported by respondents.

The AMS estimate for the "commercial" source category for 1971 (58 million tons or 1.57 lb/cap/day) is remarkably close to Paul Britton's estimate for 1967 (57 million tons or 1.57 lb/cap/day). There is also considerable consistency between the two studies with respect to the other non-residential categories, inasmuch as the AMS figures fall within the ranges of values estimated by Britton. However, the AMS adjusted residential collection estimate (128 million tons or 3.46 lb/cap/day) is substantially higher than that of the 1968 National Survey (88 million tons or 2.43 lb/cap/day).

Residential Collection Studies by the Systems Management Division of OSWMP. There is general agreement that household (residential) waste constitutes the largest source category of municipal solid waste. Two new sources of complementary data on the quantity of residential collection have recently become available, as a result of empirical work on solid waste collection systems supported by the Systems Management Division (SMD). One set of data, covering a number of residential collection routes in each of eleven city or county jurisdictions, was developed by ACT Systems, Inc., for a twelve-month period during 1972-73 under the Data Acquisition and Analysis Program (DAAP) of SMD. The other SMD-supported study was conducted by Applied Management Sciences, Inc., and involved analysis of over 20 communities during the 1971-72 period.

To a significant degree, both these studies avoided most if not all of the shortcomings of the municipal solid waste data previously available. For example, both sets of data relate primarily, if not exclusively, to residential sources, thus avoiding much ambiguity in interpreting which source(s) the reported data actually apply to. In addition, both sets of data:

(1) relate to similar recent time periods;
(2) are based on a calendar year's waste generation cycle;
(3) cover a wide diversity of city sizes and geographic locations;

Table 2

1970 NATIONWIDE SOLID WASTE COLLECTION ESTIMATES
BASED ON PRIVATE SECTOR SOLID WASTE
MANAGEMENT SURVEY

Sources	Total 1971 U. S. Waste Collection* (million tons)	Average Per Person+ (Pounds/Day)
Residential‡	128	3.46
Commercial‖	58	1.57
Subtotal	187	5.03
Demolition and Other	12	0.32
Industrial	66	1.73
Grand Total	265	7.08

*Assuming a 1970 U.S. population of 203.2 million.

+The original AMS values presented in Table 3.3, p. 3.4 of vol. 2, Analysis of Data, were in terms of waste per average collection day. Assuming 5.5 collection days per seven day week, the figures presented here were calculated by multiplying the AMS figures presented here were calculated by multiplying the AMS figures by $\frac{5.5}{7} = 0.786$ to convert to calendar days.

‡The AMS study included apartment buildings of five or more units in the "commercial" category. The figure presented here regroups this waste into the residential category on the basis of data in Table 3.2, p. 3.4 of vol. 2, Analysis of Data.

‖Assumed also to include "institution" customers.

(4) reflect weighed, as opposed to estimated, collection quantities (on either a city-wide or collection route basis).*

Previously unpublished integrated results from the two sets of individual community studies are presented in Table 3. They are to be regarded as both preliminary and subject to possible revisions, following further verification in individual cases.

Although we might wish to have ten times as many case study cities in order to increase our sample sizes, the data from these two studies are the best available on total per capita residential collection. Thus, it is all the more unfortunate not to have material composition analyses to complement them.

Although the results from these two separate sets of residential collection studies are strikingly similar with respect to both average and median values, we should be extremely cautious about leaping to nationwide conclusions on the basis of these relatively small samples.

RRD Material Flows Estimates for 1971. Because of a recognized need for more comprehensive and integrated estimates of the material and product-source composition of municipal solid waste (especially in terms of absolute nationwide magnitudes as opposed to individual local area percentages), an in-house effort was undertaken in 1973 by the Resource Recovery Division to develop quantitative estimates for major materials comprising the "post-consumer" municipal solid waste streams.+ At the same time, a cross-classification was developed between materials and consumer product categories. The principal objective was to estimate the quantities of key elements in the waste stream relevant to resource recovery and source reduction. The focus was restricted to the types of solid waste generated by the household and commercial-institutional sectors (the latter including office-type activities of governments and manufacturing enterprises).

Thus, our scope encompassed approximately the same household-commercial-institutional categories discussed in relation to the 1968 National Survey. The RRD study excluded all reference to the following categories: (1) industrial processing waste; (2) construction or demolotion residuals; (3) street sweeping (except for assumed packaging material litter); (4) heavy or bulky tree and landscape waste other than yard waste accepted in ordinary collection; (5) sewage sludge. Also excluded were any residuals relating to automobiles, auto-wrecking and

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*This is not invariably clear with respect to the AMS data sources, which require some further confirmation on this issue as well as on the question of whether bulky waste is included. Bulkies are excluded for the most part in the ACT System data.

+General results, definitions, and other issues are presented in ch. 1 of the Second Report to Congress: Resource Recovery and Source Reduction. A paper presenting detailed methodology is available: Smith, F.L. A solid waste estimation procedure: material flows approach. Environmental Protection Publication SW-147. Washington, U.S. Environmental Protection Agency, 1975. 56 p.

Table 3

PER CAPITA RESIDENTIAL SOLID WASTE COLLECTION: COMPARISONS FROM TWO RECENT STUDIES (LB/CAP/DAY)

	ACT Systems, Inc. (DAAP) 11 Communities, 1972-1973*	APPLIED MANAGEMENT SCIENCES, INC. 17 Communities, 1971-1972+
Unweighted arithmetic average of individual community data	2.38	2.35
Median	2.43	2.40
Range of values	1.72 - 3.43	1.10 - 3.40

*Based on computer print-out data supplied by ACT Systems, Inc., February 1974. For the most part, data are known to exclude bulky waste.

+Data extracted from individual city reports by Martha Madison and Cynthia McLaren, SMD, OSWMP. Data for some cities may include bulky waste and/or exclude significant portions of yard waste.

and scrapping (tires, however, were included in the rubber category). The types of materials and products are found in Table 4 on the following page.

With respect to methodology, all product-type waste (except food) was estimated independently, on the basis of available published data for specific material or product flows, including production, international trade, and marketing data, together with estimates of average product lifetimes and current recycling rates. The non-food post-consumer product waste (including "bulky" waste, such as major appliances, tires, and home furnishings) estimated for 1971 is 77.1 million tons on an "as generated" moisture content basis,* with bulky waste comprising about 7 million tons. At this point, it is worth emphasizing that our material/product estimates originate on a nationwide basis and, therefore, require no scaling.

The remaining three categories of food, yard, and miscellaneous inorganic waste were estimated indirectly on the basis of their respective average percentages in typical municipal waste composition analyses as calculated by W. R. Niessen and S. H. Chansky in their 1970 National Incinerator Conference paper.+ Thus, food, yard, and miscellaneous inorganic fractions (48 million tons) were estimated from the Niessen-Chansky ratios (Table 4).

This briefly describes the definition and origin of the 125-million-ton figure, which, for a 1971 U.S. population of 207 million, implies a per-capita figure of 3.31 lb/day. An additional step was then taken to distribute the material quantities into household and non-household source components. This was done for each material, individually, by product categories, and then aggregated into sector totals, by material (Table 5). With the important exceptions of the paper product grouping and certain of the non-paper container categories for which we drew primarily on Midwest Research Institute estimates of household versus non-household waste generation rates, much of this exercise was conducted on the basis of our own intuitive judgement and previous experience rather than on the basis of observation. Nevertheless, it was conducted in as objective a manner as possible, and the product-by-product approach guaranteed that the resulting residential vs. non-residential totals would be completely independent in derivation from other estimates based on waste collection surveys.

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*i.e., paper products were estimated on a 7 percent moisture "air dry" basis; glass and metals on a zero-moisture basis; and the remaining materials at 3 to 15 percent moisture. The total 125-million-ton waste flow is estimated to contain about 26 percent moisture overall.

+The actual calculations were based on our estimate of 70 million tons of non-bulky materials, since these were felt to be more closely comparable in composition to the typical packer-truck loadings, upon which most percentage material composition sampling has been based.

TABLE 4

MATERIAL FLOW ESTIMATES OF RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATION, BY KIND OF MATERIAL AND PRODUCT - SOURCE CATEGORY, 1971*

Kinds of Materials	Product Source Categories "As Generated" Weight Basis (10^6 Tons)						Material Totals					
							"As Generated" Basis			"As Disposed" Basis		
	Newspapers, books, and magazines	Containers and Packaging	Mayor Household Appliances	Furniture & Furnishings	Clothing & Footware	Other Products	10^6 Tons	Lb/Cap/ Day+	Per-cent	10^6 Tons	Lb/Cap/ Day+	Per-cent
Paper	10.3	20.4	---	tr.	tr.	8.4		1.034	31.3	47.3	1.252	37.8
Glass	----	11.1	tr.	tr.	---	1.0	12.1	0.320	9.7	12.5	0.331	10.0
Metals	----	6.1	1.9	0.1	tr.	3.8	11.9	0.314	9.5	12.6	0.334	10.1
Ferrous	----	5.4	1.7	tr.	---	3.5	10.6	0.281	8.5			
Aluminum	----	0.6	0.1	tr.	000	0.1	0.8	0.021	0.6			
Other Nonferrous	----	0.1	0.1	tr.	---	0.2	0.4	0.041	0.3			
Plastics	tr.	2.5		0.1	0.2	1.3	4.2	0.111	3.4	4.7	0.124	3.8
Rubber & Leather	----	tr.		tr.	0.5	2.7	3.3	0.087	2.6	3.4	0.090	2.7
Textiles	tr.	tr.	---	0.6	0.5	0.7	1.8	0.048	1.4	2.0	0.053	1.6
Wood	----	1.8	---	2.3	tr.	0.5	4.6	0.122	3.7	4.6	0.122	3.7
Non-Food Product Totals	10.3	41.9	2.1	3.2	1.2	8.4	77.1	2.040	61.7	87.2	2.308	69.7
Food Waste							22.0	0.582	17.6	17.7	0.469	14.2
PRODUCT TOTALS, INCL. FOOD							99.1	2.623	79.3	104.9	2.777	83.9
Yard Waste							24.1	0.638	19.3	18.2	.482	14.6
Misc. Inorganics							1.8	0.048	1.4	1.9	.050	1.5
TOTAL WASTE							125.0	3.308	100.0	125.0	3.308	100.0

*Smith, F. A., E. L. Smith, Resource Recovery Division, Office of Solid Waste Management Programs, Sept. 1971.
+Based on a population of 207 million.

TABLE 5

MATERIAL-FLOW ESTIMATES OF RESIDENTIAL SOLID WASTE GENERATION, BY WASTE MATERIAL CATEGORY, 1971*

	Over-Dry Weight Basis		As-Generated Weight Basis		As-Disposed Weight Basis		
	10^6 Tons	Lb/cap/day	10^6 Tons	Lb/cap/day	10^6 Tons	Lb/cap/day	Percent
Non-bulky Product Waste:							
Paper	21.6	0.571	23.2	0.614	28.8	0.762	34.3%
Glass	10.8	0.286	10.8	0.286	11.1	0.294	13.2
Metals	7.1	0.188	7.1	0.188	7.5	0.199	9.0
Plastics	3.2	0.085	3.3	0.087	3.7	0.098	4.4
Rubber & Leather	1.0	0.026	1.0	0.026	1.1	0.029	1.3
Textiles	0.9	0.024	1.0	0.026	1.2	0.031	1.4
Wood	0.5	0.014	0.6	0.016	0.6	0.016	0.7
Subtotal: Non-food	45.1	1.194	47.0	1.244	54.0	1.429	64.3%
Food Waste	5.3	0.140	17.8	0.471	15.0	0.397	17.9
Subtotal: Non-bulky Product Waste	50.4	1.334	64.8	1.715	69.0	1.826	82.2%
Yard Waste	9.0	0.238	18.1	0.479	13.9	0.368	16.6
Misc. Inorganics	1.0	0.026	1.0	0.026	1.0	0.027	1.2
Total Non-bulky Mat'l	60.4	1.599	83.9	2.221	83.9	2.221	100.0%
Add: Bulky Waste	6.4	0.169	6.4	0.169	6.4	0.169	7.6
Total Residential	66.8	1.768	90.3	2.390	90.3	2.390	107.6%

*Smith, F. A., and F. L. Smith, Resource Recovery Division, Office of Solid Waste Management Programs, Feb. 1974.

Before comparing the results achieved in this manner with those of the studies previously discussed, a further word is needed concerning the accuracy of such RRD estimates.

We previously argued that the 1968 Survey overestimates collected waste. Similarly, there should be nothing sacrosanct about the RRD material-flows estimate of 125 million tons. Basically, there are at least three errors that could have occurred in the rather involved estimating method. Briefly, they are: (1) incorrect basic estimates for individual non-food product materials; (2) failure to include one or more significant product-related materials entirely; (3) application of incorrect percentage factors in estimating food, yard, and miscellaneous inorganic waste.

This is not the place to argue the details of any of the three possibilities for error. It suffices to say that we have no way of knowing if our present estimates are too high or too low with respect to errors (1) and (3). That is, while our non-food product flow estimate (77 million tons) could easily be incorrect by 10 percent or more in the aggregate, the error could be in either direction. Resource Planning Associates independently performed much the same procedure as we did for estimating non-food product waste and estimated approximately 10 million tons less.[7] Because we have confidence in the two largest non-food material/product estimates--those for paper and glass which together comprise two-thirds the weight of our total non-food product estimates--we have more confidence in the non-food product sum of 77 million tons (2.04 lb/cap/day) than in the other categories. As previously noted, the estimating factors we used to calculate food and other non-product fractions are based on the work by Niessen and Chansky in synthesizing previous percentage composition studies. We feel that the ultimate data base here is indeed quite ambiguous and weak, but still, we should not expect much more than a 25 percent error in either direction for the sum of these three indirectly estimated categories.*

If any major tonnage materials or products have been omitted, these would cause us to underestimate total waste. We feel that we are more likely to have overlooked a number of small items than any single large item, and we are somewhat less confident regarding the non-paper fraction of commercial-institutional categories than in the household sector estimates.

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*In a 1972 extension of the 1970 work, Niessen and Alsobrook[7] revised the as-discarded weight-percentage contribution of food, yard, and miscellaneous inorganics downward somewhat from 40.7 percent to 37.3 percent of (non-bulky) total waste, based on additional composition studies. Use of these later factors would reduce our total waste estimate by about 6.5 million tons.

It should be noted in this regard that any overestimate or underestimate in the non-food product categories will be compounded by a factor of about 1.67 due to our percentage method of estimating food, yard, and miscellaneous fractions.*

Comparative Results and Conclusions for The Residential/Commercial-Institutional Sectors

We now have three independent estimates for the total quantity of residential and commercial solid waste flows: the 1968 National Survey (1967 data), as evaluated by Paul Britton; the 1970 figures from the AMS Private Sector study; the RRD materials flows estimates for 1971. The three sets of data are summarized in Table 6, with both the 1968 National Survey and the AMS Private Sector data "normalized" to 1971 by assuming growth in waste collection over the relevant periods equivalent to growth in total National real expenditures on non-durable consumption goods.

The following comparative results for these three sets of 1971 estimates are apparent from Table 6:

(1) total waste varies from a low of 125 (RRD) to a high of 191 (AMS);

(2) the 1968 National Survey and RRD estimates are in reasonably close agreement--within about an 8 percent difference--for residential waste. But RRD shows only 55 percent of the National Survey's 64 million tons of commercial-institutional, which accounts for most of the overall difference of 36 million tons;

(3) also, the National Survey is in very close agreement with the Private Sector Study on Commercial-Institutional waste (within 7 percent), but there is a 34 million ton difference in the residential sector estimates;

(4) the RRD figures are more than 30 percent lower for residential and more than 40 percent lower for Commercial-Institutional than the Private Sector Survey estimates, with a total difference of about 66 million tons.

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*It should be possible, in principle, although we have not yet done so, to develop a better, more direct empirical estimate for food waste using the material flow approach as a check on waste-collection samples. Improvement in our estimate of this important category would significantly increase our confidence in the overall total estimates. Improvement estimates for yard waste must rely on further direct field sampling.

Table 6

COMPARATIVE NATIONAL ESTIMATES OF RESIDENTIAL AND COMMERCIAL-INSTITUTIONAL SOLID WASTE FOR 1971

	1968 National Survey*	AMS Private Sector Survey+	RRD Materials Flows‡
	----------Million Tons----------		
Residential	97.5	131.5	90.1
Commercial-Institutional	63.8	59.7	34.9
Totals	161.4	191.2	125.0
	----------Lb/Person/Day----------		
Residential	2.58	3.48	2.39
Commercial-Institutional	1.69	1.58	0.92
Totals	4.27	5.06	3.31

*From Table 1, adjusted upwards by 11 percent, to account for growth equivalent to the change in real U.S. personal consumption expenditures on non-durable goods between 1967 and 1971.

+From Table 2, adjusted upward by 2.5 percent growth factor for 1971 over 1970.

‡From Table 5.

Residential. Of the three estimates of residential solid waste summarized in Table 6, the two lower values (1968 National Survey and RRD Material Flows) were seen to be in reasonably close agreement at 2.58 and 2.39 lb/cap/day. Lower values are supported by the results of both residential collection studies (Table 3). Both the average and median values of the 17-community AMS data and the 11-community ACT Systems data are grouped within a few percentages of one another, with averages at 2.35 and 2.38 and medians at 2.40 and 2.43 lb/cap/day, respectively.

Both the AMS and ACT Systems data are presumed to relate to non-bulky residential collection, either wholly or primarily. On this basis, they should be increased by about 0.15 lb/cap/day to correspond with the RRD estimate, which explicitly includes household bulkly items, and the other two estimates, which implictly include them. On the other hand, the two residential collection studies represent data for a somewhat later time period. Adjustment for this factor would reduce these values somewhat (2 to 4 percent). The net effect should be a slight upward adjustment of less than 0.1 lb/day for purposes of comparison against 1971 residential figures, which include bulky product waste items.

These four sets of data on residential waste--the 1968 National Survey, the RRD Material Flows Analysis, and the two (small sample) residential collection studies--when adjusted to a common 1971 basis, thus estimate the residential waste fraction at between 2.4 and 2.6 lb/capita/day, including moisture.

There is also further evidence that the "true" National average lies at a point close to these values. The best estimate that we have for wastepaper generated in the residential sector is a National average for 1971 of 0.57 lb/capita/day (after recycling), on an oven dry basis.* Our best data on the percentage of paper in residential collection come from a three-city study conducted by ACT Systems.[9] In these three cases, the annual average percentage varied only between 29.5 and 31.0. We do not have good data on the percentage of moisture in collected wastepaper, which is an important variable in any attempt to reconcile material flow estimates with waste collection values. However, if residential wastepaper collection averages somewhere between 20 and 30 percent moisture (on a wet weight percentage basis), then the wet weight of residential wastepaper generation lies somewhere between 0.71 and 0.82 lb/capita/day. If paper is in fact about 30 percent of residential waste on average, then a value of wastepaper between 0.71 and 0.82 lb/capita/day implies a National average residential waste between 2.38 and 2.7 for 1971.+

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*See Table 5.

+For the lower moisture percentage (20 percent of wet weight of paper): 0.57 lb ÷ 0.3 = 2.375 lb/cap/day. For the higher moisture level (30 percent): 0.57 lb ÷ o.7 ÷ .3 = 2.714 lb/cap/day. If paper is more than 30 percent of residential waste, then total waste projected from a given wastepaper generation rate will, of course, be lower than the values estimated here.

On this basis, values of total residential waste higher than 2.7 or 2.8 lb/capita/day would require that the paper being collected is extremely wet--more than 30 percent or so moisture--or that paper is a lower fraction of residential waste than we think it to be--i.e., lower than 29 percent. A National average value of 3.5 lb/capita/day is inconsistent with existing evidence on the quantity of household waste-paper generation, the percentage of paper typically observed in residential collection, and the types of moisture levels typically recorded in residential waste. Additionally, a value of 3.5 exceeds the highest values measured in either the ACT System or the AMS residential collection studies.

Our conclusion on residential waste collection is that the National average value for 1971 on a wet weight basis very likely lies within the range of 2.3 to 2.7 lb/capita per day (87 to 102 million tons). Since we do not know as much as we would like to about either the average moisture content of collected waste or the average moisture content of its individual constituents, more precise reconciliation than this seems impossible at present, given the existing kinds and sources of data and evidence.

Commercial-Institutional. We have seen considerable divergence between the RRD materials-flow estimate of 35 million tons (0.92 lb/capita/day) of commercial-institutional waste generation and the two survey estimates whose time-adjusted values fall between 60 to 64 million tons (1.6 - 1.7 lb/cap/day). We lack independent field study estimates based on measured (weighed) collection data to serve as solid evidence on this subject. Nonetheless, we cannot justify estimated collection as high as 60 million tons, on the basis of our material-flow data.

Little work has been done to characterize the material composition of commercial-type waste, but the consensus appears to be that commercial and institutional sources have a very high percentage of paper--higher than 50 percent and perhaps as high as 75 percent on the average. Although there is no comprehensive empirical basis for determining precisely what the percentages of paper in the commercial waste stream is, our material-flow estimates indicate that it is unlikely that any more than 15 million tons of non-recycled wastepaper (oven-dry weight) was generated by all non-residential sources in 1971. At 25 percent moisture when collected, the paper fraction would then weigh about 20 million tons. If paper were only 50 percent of the commercial sector waste, then 40 million tons of total waste would be projected for that sector in 1971.

We think it unlikely that this sector's wastepaper would have an average moisture content higher than 25 percent, or that paper would constitute less than 50 percent of the wet weight of collection from this sector. Therefore, on the basis of this type of evidence (inferential and circumstancial as it is) it is difficult to understand how 1971 commercial sector waste collection (as we define it) could be much higher than 40 million tons, or about 1.06 lb/capita/day as a National average.

Aside from possibilities of overestimation on the part of questionnaire respondents or possible errors involved both in converting reported volume rates into tonnage terms and sample population data into total population data, the most logical explanation for high collection-based estimates vis-à-vis low material flow-based generation estimates for the commercial sector is differing definitions of the sector in question. Thus, questionnaire respondents or interviewees may, in some instances, have interpreted the term "commercial" to include a broader range of establishments overlapping into some industrial processing and manufacturing assembly categories. In addition, collection routes that were predominantly commercial may, as a matter of convenience, have been reported as entirely commercial. Finally, there may have been some reporting of materials collected which were subsequently salvaged for recycling rather than landfilled or incinerated. All this is, of course, speculative. The simple fact is that we do not presently have a satisfactory or "scientific" explanation for the 20 to 25-million-ton-difference in estimates for the commercial sector.

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15. Supplementary Notes

16. Abstracts

This report provides data on the total quantity of residential and commercial solid waste composition for the years 1968, 1970, and 1971. The results of several national surveys are compared and evaluated.

17. Key Words and Document Analysis. 17a. Descriptors

*Solid waste disposal,
*Management planning,
*Surveys,

Refuse disposal,
Collection,
Composition(property),
Tables(Data),
Paper,
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Metals,
Plastics,
Elastomers,
Leather,
Textiles,
Wood,
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Food.

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